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Portrayal of the Present State of Biomedical Science and Technology at Regional Science Centre, Jaipur

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Abstract

The rationale behind the development of the concept for the Biomedical Revolution Gallery at the Regional Science Centre, Jaipur, Rajasthan, India, rests on two fundamental concepts. One, that the progress of medicine from what it was in prehistoric times, to what it is today, was not a continuum of inventions and discoveries, each supplementing and adding to the existing corpus of knowledge but was a series of bursts, sometimes totally unrelated to the existing knowledge in the field and two, it borrowed heavily from fields far diverse and those that have no direct bearing whatsoever with the fundamental foundations of medicine, biology and chemistry. These two concepts recur repeatedly and are emphasised at regular intervals in the Gallery. Besides, the extensive use of vivid three dimensional visual components like period settings and dioramas supported by technology makes the Gallery very visual and emphatic.

Biomedical Revolution as a Revolution

It is essential to understand the nature of a revolution. Thomas Kuhn, in his classic "The Structure of Revolutions" mentions that "Scientific revolutions are inaugurated by a growing sense, ...,often restricted to a narrow subdivision of the scientific community, that an existing paradigm has ceased to function adequately in the exploration of an aspect of Nature to which that paradigm itself had previously led the way........and the sense of malfunction leads to a crisis that is a prerequisite to the revolution[1]". A slight elaboration is in order here, and I do that using the example of the Copernican revolution or the Einsteinian revolution. The Ptolemaic astronomy and Aristotelian astronomical principles were considered entirely adequate to explain and indeed understand the corpus of astronomical knowledge as it existed till Galileo came up with certain startling observations that the existing paradigms entirely failed to address. Similarly, Newtonian mechanics was comfortably placed to explain all observed mechanical phenomena entirely till certain observations made by Michelson and Morley rendered it insufficient. An entirely new mechanics had to be formulated. Similarly, several biomedical concepts had to look for newer paradigms to explain certain new and startling observations from the 17th Century to the 20th Century to explain them. As an example I quote the fact that, though it was known that the heart pumps blood through the body, the facts that the volume of blood in the body was limited, and that the heart seems to pumping a lot of excess blood during a lifetime, brought the understanding of the mechanics of flow of blood through the body to a standstill till the advent of the microscope made the visualisation of capillaries possible and Harvey correctly surmised that the it was the same blood that circulated throughout the body time and again. This required a totally and radically different understanding of the mechanics of blood circulation and also new instruments and techniques borrowed from an entirely different field of science – optics- in the form of a microscope, to grasp. There are several such milestones in biomedical technology, which exhibit a paradigm shift from one school of thought to a new one, and these are the milestones that the gallery attempts to portray as a story. This story is told using certain landmark exhibits - by landmark, I mean exhibits, which portray these paradigm shifts interspersed with explanatory and supplementary exhibits to tell the story in detail. I will attempt to explain each of these in a little detail[2].

Rhinoplasty in ancient India.

Medicine has naturally had a long tradition in ancient civilisations, including India. Surgery was performed but it was a last resort. The methods employed by surgeons were not very refined and therefore, medication was the first choice. A break from tradition occurred with Sushruta (circa 600 BC)[3]. Sushruta was no doubt a skilled surgeon, but even his surgeries were not much sought after by ordinary patients. It was a particular necessity among certain members of the society that spurred rhinoplasty and refined it to a fine art in ancient India. Criminals in ancient India had to endure a punishment, which involved cutting off the nose of the criminal. This procedure finds reflection even in present day usage in several Indian languages in the form of an idiom "Naak katwana", meaning "cutting off the nose" to indicate a shameful act. The rationale behind this punishment was manifold. First, a person may lose his limbs or even head by means like accidents, wars etc. and losing a nose, while keeping the face intact, is not at all common. Hence, absence of a nose certainly signified an induced loss. Second, the nose being a prominent feature of the face – the most visible and viewed feature of a human being, is most liable to be missed on observation and therefore this punishment certainly served the purpose of branding criminals. One might justifiably hide any other part of the body without raising undue suspicions, but not the nose. Third, loss of nose did not often seriously impair the quality of biological life of the person, though it might seriously affect other aspects of his life – social and psychological. It could therefore be deemed a relatively humane mode of punishment while certainly introducing a marker indicating delinquency. This is good enough for the society, but it was not a happy situation for the criminal. Criminals therefore sought a means to get the cut nose reasonably reconstructed so that they could lead a relatively normal life. Further, even in the absence of anaesthesia, criminals who were desperate to get back into the mainstream, were willing to endure some pain involved in surgery. Sushruta used these circumstances to develop rhinoplasty – reconstruction of the nose - to perfection, and is therefore justifiably hailed as the father of modern reconstructive surgery[4]. Reconstructive surgery, which otherwise would not have even contemplated arose therefore, out of a societal necessity and was extended to other parts of the body like correction of mutilated ear lobe defects and techniques for repair of torn ear lobes, cheek flap for reconstruction of absent ear lobe, repair of accidental lip injuries and congenital cleft lip, piercing children's ear lobes etc. This is elaborated in the period setting "Surgical Traditions of Ancient India[5]".

Advancements in Anatomy and Physiology

Moving on to modern times, medicine was for long hampered by the fact that the interior of a human body was a mystery. The fact that it was taboo to cut open even a dead human body and there were religious injunctions against it, prevented humankind from really knowing the anatomy and physiology of a human body. It was when Andreas Vesalius in 1543 defied social and religious norms to dissect human bodies, and based on his observations, published his great anatomical treatise, that the knowledge of anatomy took off. The illustrations by an unknown artist set a new standard for the understanding of human anatomy[6]. Similarly, in physiology in the 17th century, William Harvey established that the blood circulates within a closed system with the heart serving as a pump. This understanding provided an impetus that could not have been possible using the earlier corpus of knowledge and is explained in the exhibit "Past and Present – A study in contrast".

An exhibit depicting the contrast between past and present practices in medicine.

Cell Biology

Today every high school student learns that cells are the

understanding did not exist till the recent past. In the 17^{th} century, Anton von Leeuwenhoek[7], with an object held close to the lens he had made, was first able to see minute "animalcules" and discover that tissues had complex inner structures. Others like Robert Hooke, Matthias Schleiden and Theodor Schwann, and Rudolf Virchow, Ludwig Aschoff, and Carl Rokitansky developed further insights. Proceeding to sub cellular biology, in the 20^{th} century, Ernst Ruska made the first electron microscope in the early 1930s. With this primitive apparatus and, later, more sophisticated machines, the rich subcellular structure became visible. With these developments, several heretofore unknown facts like fertilizations and the detailed mechanism of sexual reproduction, embryology, and even cancer became possible to be understood, since these involve the cellular structure[8,9]. This is shown in the exhibit on "Microscopy" in the Gallery.

Anaesthesia

Humans have been operating upon one another since the Stone Age but before the invention of effective pain-killers, surgery remained an agonising last resort. Patients were held or strapped down and many died of shock on the table. Doctors relied on speed, not accuracy, so surgery was a hit-and-miss affair - as few as 50 per cent of patients survived. Those who did certainly did not enjoy the experience. Despite ongoing and often desperate efforts to dull the pain - from opium and alcohol to throttling patients to stupefy them or even freezing limbs prior to amputation. Nothing really worked until the discovery that inhaling certain gases induced blissful unconsciousness. And thus was anaesthesia born[10].

Humphry Davy was first to realise the pain-killing effects of nitrous oxide (laughing gas), originally used as a party drug in "frolics". By the 1840s, it was being used to ease dental extractions, but its effects were too short-lived for more major surgery. That had to wait for the discovery of ether, a stronger anaesthetic also popular as a party drug that was first used in surgery by William Thomas Green Morton at Boston's Massachusetts General Hospital in 1846[11]. The following year, Edinburgh gynaecologist Sir James Young Simpson pioneered the use of chloroform, simultaneously discovered by three independent researchers in 1831, to ease the pain of childbirth. Interestingly, it was till then believed that women were fated to endure its agonies as a punishment for original sin. Anaesthesia also therefore, in a way, worked towards eliminating stereotypes against women. This is portrayed in the exhibit on Anaesthesia.

Asepsis and Antisepsis

Infection control remained problematic so long as its causes remained unknown and infections were routinely ascribed to the action of evil spirits and later to "miasma" (bad air). The real culprits - bacteria - were first spotted in 1683 by Dutch merchant Anthony van Leeuwenhoek, inventor of the microscope, who described the "animalcules" (tiny animals) he saw swarming in his own saliva. By 1847, Hungarian doctor Ignaz Semmelweis had noticed that women delivered by midwives were much less likely to die of childbed (puerperal) fever than those delivered by medical students fresh from the dissecting rooms. Semmelweis deduced that "putrid particles" were somehow being transferred from the corpses they had been cutting up to the new mothers' wombs and ordered the students to wash their hands in lime chloride. Cases of childbed fever dropped, but Semmelweis's theories were not widely accepted until after his death.

"Hospitalism", as the diseases septicemia, erysipelas, and pyemia began to collectively be known was the root of the overwhelming mortality rate in the hospital setting. Joseph Lister, Regius Professor at the university in Glasgow was aware of this, and he studied the works of other prominent scientists to learn that the infections were not caused by a chemical reaction, or an oxidation, that occurred when oxygen touched the wound, but by tiny organisms from the air.

The problem that vexed Lister the most was that of sepsis following compound fractures, a fracture in which the skin is broken and the bone exposed. Such a malady required surgery and had an extremely high mortality rate, especially when the individual remained in the hospital following the surgery. After learning of Louis Pasteur's work and doing his own experiments, Lister knew that he needed to keep the wound free of the microbes that were causing the infections. Joseph Lister had heard of Carbolic Acid being used to remove the odours from sewage and decided to try to use it on a small boy with a compound fracture of his leg.

Sepsis and Antisepsis - Joseph Lister's work.

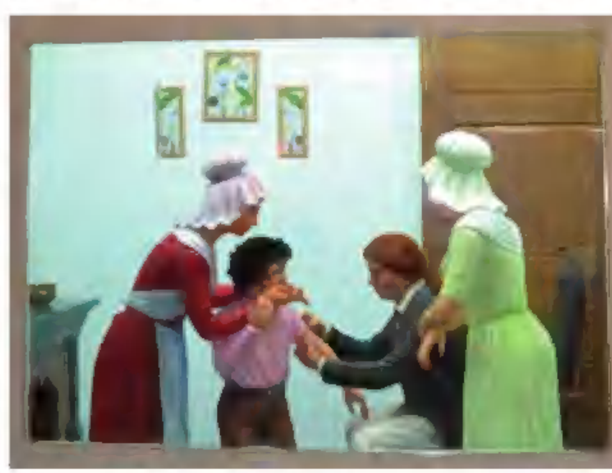
The wound did not suppurate following surgery and the only injury was that the acid was burning the boy's skin. Lister explained the case and the following ones in which he perfects his method in his essay "On a New Method of Treating Compound Fracture, Abscess, etc.". Lister also discussed his removal of abscesses, a surgery considered an unnecessary risk during those days. Lister's survival rate was astonishing and other surgeons and professionals began to pay notice[12]. Gentler disinfectants and surgical rubber gloves were introduced; instruments, ligatures and wound dressings were sterilised, and post-operative mortality rates plunged.

Meanwhile, Louis Pasteur[13] was busy propagating the germ theory - that microscopic airborne organisms invading the body were responsible for infections. Asepsis, coupled with the developments in anaesthesia, meant that riskier operations into regions like the abdominal cavity could now be undertaken. The next step was antisepsis-starting with a germ-free environment, as opposed to destroying bugs after the event. Today's operating theatres are sterile. This is portrayed vividly in the exhibit "Antisepsis and Joseph Lister", in the form of a period setting.

Immunization

In India, immunization against infectious diseases has been practiced for at least 4,000 years. In ancient India, every village had a temple to a certain goddess named Sheetla Devi (the cool goddess) in northern India, Mariamma (the epidemic goddess) in southern India, and several other names in other parts of the country. The temple for this goddess was usually outside the village limits, possibly to limit infection, and was open-air, exposing it to the harsh sun and rains. When small pox broke out in a village and a patient happened to be cured of the disease, he (or she) was made to bang his head on a stone called the 'bali peetham' outside the temple. After this incident, several rituals were practiced during which all people in the village were required to bang their heads lightly on the same stone to guard them against small pox. This process was called variolation, which slowly spread to the west primarily through the efforts of Lady Mary Wortley Montague of England[14].

Edward Jenner was born in 1749 in Berkeley, Gloucestershire. While Jenner's interest in the protective effects of cowpox began during his apprenticeship with George Harwicke, it was 1796 before he made the first step in the long process whereby smallpox, the scourge of mankind, would be totally eradicated. For many years, he had heard the tales that dairymaids were protected from smallpox naturally after having suffered from cowpox. Records show that Jenner heard a dairymaid say, "I shall never have smallpox for I have had cowpox. I shall never have an ugly pockmarked face." It fact, it was a common belief that dairymaids were in some way protected from smallpox. Pondering this, Jenner concluded that cowpox not only protected against smallpox but also could be transmitted from one person to another as a



Immunization by vaccination - The work of Louis Pasteur.

deliberate mechanism of protection. In May 1796, Edward Jenner found a young dairymaid, Sarah Nelms,

who had fresh cowpox lesions on her hands and arms. On May 14, 1796, using matter from Nelms' lesions, he inoculated an 8-year-old boy, James Phipps. Subsequently, the boy developed mild fever and discomfort. Nine days after the procedure he felt cold and had lost his appetite, but on the next day he was much better. In July 1796, Jenner inoculated the boy again, this time with matter from a fresh smallpox lesion. No disease developed, and Jenner concluded that protection was complete. For this remarkable work, Jenner was elected a fellow of the Royal Society. However, many naturalists in England dismissed his work as pure nonsense[15].

Louis Pasteur[16] knew about the work done by Edward Jenner regarding smallpox. Pasteur reasoned that if a vaccine could be found for smallpox, then a vaccine could be found for all diseases though he did not know how Jenner's vaccination worked. So he had to proceed by trial and error. In April 1881, Pasteur announced that his team had found a way to weaken anthrax germs and so could produce a vaccine against it. Pasteur and his team turned next to the disease of rabies. Most human victims of rabies died a painful death and the disease appeared to be getting more and more common in France. In 1885, a young boy, Joseph Meister, had been bitten by a rabid dog, and was brought to Pasteur. The boy almost certainly would have died an agonising death if nothing was done so Pasteur took the risk on using his untested vaccine. The boy survived and Pasteur knew that he had found a vaccine for rabies. Three months later, when he examined Meister again, Pasteur reported that the boy was in good health. Starting with smallpox, many major diseases like Polio, of the past have now been totally eradicated by a concerted programme of regimented vaccinations through the Globe, marking the end of a scourge which at one time seemed unconquerable[17], but the beginnings of this achievement started with the paradigm shift in thought by Pasteur, wherein he correctly deduced that introduction of a weakened or killed strain of a pathogen will sensitise the body against any future virulent attack by the same pathogen. This principle gave birth to the new science of immunology and Pasteur's pioneering work on smallpox vaccination is portrayed in a period setting in the Gallery marking the birth of scientific immunisation by the process of vaccination.

Antibiotics

There was a time, barely a century ago, that even a minor infection could kill you. In fact, infectious diseases were once the main killers of children and young people. Once the role of bacteria became understood, the race for antibacterial medications was on. First off the blocks were the sulfonamides, developed from dyes found to combat streptococcal infections (such as puerperal fever and pneumonia) by preventing bacteria multiplying, starting with the discovery of Prontosil by German pathologist Gerhard Domagk. However, the sulpha drugs were by no means proof against all bacterial infections.

Antibiotics - The works of Alexander Fleming.

In 1928, Scottish bacteriologist Alexander Fleming[18] noticed that a fungus mould growing on a petri dish was producing a substance that killed staphylococcal bacteria. He named it penicillin. It was not until the outbreak of World War II, when Australia's Howard Florey and Ernst Chain successfully extracted and stablilised the active principle, that its lifesaving potential was realised. However, despite subsequent mass production and the development of related antibiotics, the penicillin seemed powerless against certain infections, such as tuberculosis and typhoid. But by 1943, US researcher Selman Waksman developed streptomycin that cured these diseases and more. Other antibiotics joined the arsenal, and today they are among the most commonly prescribed drugs.

Lately, however antibiotics are in danger of being superseded by evolution of microorganisms. Our addiction to antibiotics is "breeding for resistance", knocking out weaker strains of bacteria, allowing stronger ones to flourish. Today, old killers such as pneumonia and tuberculosis have developed resistance to many antibiotics, and the focus is on finding new ones effective against "superbugs". The development of antibiotics is explained in the exhibit "Antibiotics and Alexander Fleming" in the Gallery.

Genetics and Inheritance

People have known about inheritance for a long time. They had noticed that children resemble their parents and were already practicing domestication of animals and plants, selective breeding for good characteristics. There was however, a marked lack of understanding of the exact mechanisms involved in inheritance and genetics[19].

The Greeks, as usual were first off the block and Theophrastus proposed that male flowers caused female flowers to ripen. Hippocrates speculated that "seeds" were produced by various body parts and transmitted to offspring at the time of conception. Aristotle thought that male and female semen mixed at conception. Aeschylus proposed the male as the parent, with the female as a "nurse for the young life sown within her".

There were different theories proposed to explain the similarities and dissimilarities between individuals: The blending theory of inheritance suggested that the mixture of sperm and egg resulted in progeny that were a "blend" of two parents' characteristics and the idea that individuals inherit a smooth blend of traits from their parents. This was later disproved and it was shown that traits are composed of combinations of distinct genes rather than a continuous blend. Another theory that had some support at that time was the inheritance of acquired characteristics or the belief that individuals inherit traits strengthened by their parents. This theory of Jean-Baptiste Lamarck is now known to be wrong – the experiences of individuals do not affect the genes they pass to their children[20].

It was Johann Gregor Mendel[21,22] who in 1866 published the results of his meticulous work using pea plants that laid the groundwork for modern genetics. This was a paradigm deviation from the existing line of thought regarding inheritance of characters. So was Darwin's monumental work, which again brought in a totally revolutionary and new line of thought that is even today opposed in many circles. A series of other related discoveries by scientists like Miescher, Morgan, Fischer and others led ultimately to the grand finale when in 1953, James Watson and Francis Crick determined the structure of the DNA molecule, which led directly to knowledge of how it replicates[23,24]. The understanding of genetics by humanity is a classical example of how sometimes a totally different approach is essential to arrive at new knowledge when all existing avenues of scientific investigation have been exhausted. The work of Crick and Watson continued to spawn a whole series of new discoveries aided actively by newer technologies, and today we have a huge corpus of knowledge which help us understand what did not, a mere five decades ago[25]. It is a classic example of a "Scientific Revolution". The steps leading to this revolution has been depicted in many exhibits in the Gallery, each time emphasizing the departure from the beaten path to arrive at new knowledge.

I will briefly mention some other paradigm shifts in the field of biomedical revolution that are depicted in the galleries.

Pharmacology

Existing thought: Mankind had, very early in the course of civilization, discovered that certain substances of plant, animal or mineral origin had ameliorative properties in curing certain ailments. Early pharmacology consisted of isolating the active components of these substances and searching for newer and more effective substances, more often than not, depending on serendipity for discovery of new drugs[26].

Synthesis of drugs with desired/designed properties started with Wohler who synthesized organic compounds from inorganic substances and the subsequent work done by Rudolf Buchheim and Oswald Schmiedeberg. Newer drugs began to be created, reducing dependence on naturally occurring substances. However even now the "one size fits all" technique is followed by most drug designers.

This sometimes resulted in adverse drug reaction among some patients to a prescribed drug. Ingesting and injecting drugs and chemicals indiscriminately into the bloodstream hoping that they will be delivered to the diseased or infected tissue is something shooting at a crowd blindfolded. It may cause more harm than good.

The next paradigm shift is expected from the results of works being done in two different directions[27]. Anything that happens in the body, be it growth, disease, everything is dictated by genes. Even diseases that are clearly caused by external agents are influenced by genes. And then there are diseases that can be directly attributed to genetic defects. Such diseases can be prevented by appropriately tinkering with the genetic makeup of the individual. Such techniques are now available. Secondly advanced drug delivery systems like carbon nanotubes, nanorobots, buckyballs etc., are being explored as vehicles to focused delivery of drugs reducing side effects significantly[28]. All these concepts are depicted in the Gallery.

Psychology and Psychiatry

Early human beings thought that mental illnesses were of mysterious origin or the work of the devil. Treatments were equally weird and consisted at best of techniques like faith healing and praying, and worst, chaining and incarceration of patients with psychoses for life[29]. The works of Freud[30], Adler[31], Jung[32], Penfield[33] and others led to the advent of psychology and psychoanalysis, which represents the first paradigm shift in the amelioration of several mental illnesses.

The way such patients were treated earlier betrayed a lack of knowledge of the real source of such illnesses. Restraining mentally ill patients to asylums and administering what were known as shock therapies (administering several kinds of shocks including malarial therapy for general paresis, insulin shock therapy, cardiazol shock therapy, and electroconvulsive therapy), were the general methods used. The apparent success of the shock therapies, despite the considerable risk they posed to patients, also led to more drastic forms of medical intervention, including lobotomy.

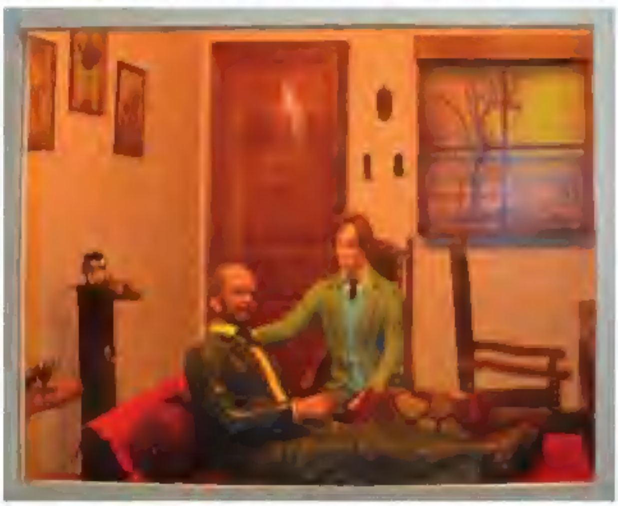
Despite the work of pioneers mentioned above, there existed two very important lines shortcomings till the beginning of the twentieth century, which dominated the treatment of mentally ill. An inability to pinpoint the organ and the exact region therein, where mental illnesses originated and the brute force methods employed to contain and apparently cure such illnesses. The identification and mapping of the brain as the source and hence the organ which should be dealt with either medically or through surgery, came about in the beginning of the twentieth century. The works of António Egas Moniz[34], who shared the Nobel Prize for Physiology or Medicine of 1949 started using lobotomy or leucotomy, which involved what came to be known as psychosurgery, a procedure where parts of the pre frontal cortex of the brain were removed or connections severed, to ameliorate mental illnesses. Though such procedures had several detractors, the study of behaviour of deliberately or accidentally lobotomised or partially lobotomised patients by researchers like Vilayanur S. Ramachandran[35,36] have since led to heretofore unknown insights into the working of the human brain. Simple therapies for problems like the "Phantom limb" have been devised.

The work of Franco Basaglia[37] in Italy, on the methods employed to treat institutionalised patients was also another paradigm shift in the way society looked at such illnesses. Observing that many of the symptoms of mental illnesses amplified because of institutionalisation, and that such symptoms vanished when they were freed of the forcible restraint practised in institutions, Basaglia concluded that many so called abnormal behavioural traits would dissolve when the patients were freed from the asylums. He advocated that allowing the mentally ill to integrate into the society and live as normal a life as is possible can be a better option. Pharmacology and newer imaging techniques also actively aided in development of newer treatments. Though not very much in practice the free association psychoanalysis pioneered by Freud represented a radical shift from earlier crude techniques to methods that concentrated on human thought processes. So did the works of other pioneers mentioned above. This is depicted by graphic panels and a period setting of Freud practising psychoanalysis in the Gallery.

Medical Imaging

Humankind has always been handicapped by its inability to look into a live body and find the source of the ailment and this had made medicine a science that

often worked by trial and error. The first noteworthy step in body imaging took place in the turn of the 20th century by Wilhelm Konrad Roentgen[38], who discovered x-rays in 1895, a discovery for which he received the first Nobel Prize for Physics in 1901. Imaging science has evolved in three stages. In the first stage, the aim was to develop imaging techniques to define the anatomic features and functions of the internal organs. Other methods for this purpose were also used, including ultrasound and radioactive tracers, and contrast agents were developed to reveal previously indiscernible structures. In the second stage, the interior of the heart and blood vessels were delineated by angiography and other new tools including Computerised Tomography (CT/ CAT scan)



Psychology and Psychiatry - A period setting showing the work of Sigmund Freud.

and Magnetic Resonance Imaging (MRI), which permitted resolution of very small structures throughout the body. As a third stage, imaging methods are now being used to guide therapy directly – from long-term guidance of cancer therapy to immediate, on-line guidance of minimally invasive surgery as in case of laparoscopic and robot assisted surgeries. It can clearly be seen that engineering, chemistry and physics played a major role in development of such non invasive imaging methods that helped the therapist clearly see the interiors of the human body without taking recourse to invasive techniques.

The Gallery

The Gallery is laid out in a six thousand square feet area with forty four interactive exhibits, period settings and graphic panels, not arranged in chronological sequence, but as a series of clusters depicting paradigm shifts in scientific thought that led to the development of biomedical science as bursts of knowledge rather than as an unbroken continuum.

It begins with a quote in the Indian classical language Sanskrit on medicine and is followed by a visual seeker – a large curved graphic panel in the background with a touch screen monitor on a rotary platform in front. The graphic covers the whole history of medicine from prehistoric times to the present in the form of a collage. The touch screen monitor when pointed towards one section of the graphic, displays a multi layered animated/graphic/video information database giving further details about that period of civilisation. The touch screen enables the visitor to get in depth information about key paradigm shifts in the history of medicine. This is followed by a series of exhibits depicting the contrast between past and present practices in medicine and dioramas about the Indian tradition in medicine. An exhibit showing another paradigm shift – the advent of hospitals - which saw patients going to a central location equipped with expertise and infrastructure to be cured, rather than the wait for the wandering medicine man to visit and treat his ailment. The next exhibit depicts a period setting of surgical traditions in ancient India – talking about rhinoplasty, which arose as a result of societal needs as described earlier.

The second part starts with a discussion about the 'Age of Biology' followed by a series of exhibits which show how there were several things that were not understandable using the existing corpus of knowledge in biology at that time, like how blood circulates, how the sex of a child is determined, what caused infectious diseases, lifestyle diseases, why some diseases were curable, while some were not, psychopathology etc.

This is followed by an exhibit which talks about 'Challenges that spurred the Revolutions', which summarises the conundrums of those periods in history, when medicine came to a standstill. Thereafter, come another series of exhibits, which talk about the paradigm shifts that created understanding of each of these dead ends, like Microscopy, Immunology, understanding of the germ theory of diseases, sepsis

and antisepsis, antibiotics, psychology and psychiatry etc. Each of these are set in an eye catching period setting, capturing a particularly poignant scene that marked a turning point in the understanding of heretofore unknown concepts, featuring the pioneers in the these respective fields. Thus there are period settings showing pioneers like Sushruta, Jenner, Lister, Freud and Fleming at work.

Each of these works are elaborated in further detail in a series of exhibit clusters. There is a visual seeker talking about the history of immunisation, the specifics of immunology, psychoanalysis, the works of neuro-psychiatry pioneers, antibiotics and their mode of working antisepsis and how it works etc.

Traditional pharmacology is discussed in one exhibit and then the newer technologies like tailor-made drugs, advanced drug delivery systems, nanotechnological methods of drug delivery, genetic medicine etc. are discussed to show several paradigm shifts in the field of pharmacology.

There was a time in the history of medical technology, when loss of an organ meant living without it for life, or simply dying. The concept of transplantation and implants and indeed augmenting existing human prowess by implanting devices that perform better or over a wider spectrum than natural organs is discussed in detail. This future trend might create an "Augmented Human Being" as described in an exhibit by the same name. The shift in thought brought about by the conception of transplants and implants is talked about in a series of five exhibits.

Understanding of heredity, genetics and the genome marked another landmark. This is elaborately discussed in a cluster of nine exhibits, starting with the description of the works of Mendel, Crick and Watson and ending with a period setting of the Human Genome Project. In between, the techniques of genetic engineering, like Polymerase Chain Reaction, Gel Electrophoresis and DNA Microarray, all technologies that aided the Human Genome Project have been elaborated using interactive exhibits. The possibilities that open up for therapy on account of the mapping of the human genome is established in this section.

Though the advent of microscopy and the use of dissection for seeing inside the human body brought

Advances in Medical Imaging showing non invasive imaging methods.

about a paradigm shift in the understanding of anatomy and physiology of the human organism, they were not of much help in looking into a live human body to detect diseases and disorders. Non invasive imaging techniques, starting with the discovery of X-Rays and their use in body imaging, overcame this handicap. Extremely detailed imaging of a live human body using non invasive techniques were developed one after the other and this is depicted in a series of highly interactive exhibits like 'Magnetic Resonance Imaging', 'Endoscopy', 'CT Scanning' etc.

The present and future of biomedical technology, as we see it today, is discussed in another series of seven exhibits, where stem cell therapy, telemedicine, robotic surgery, laparoscopic surgery, cloning for organ harvesting etc. in an interactive format.

The Gallery ends with a highly interactive format exhibit "Ask the Expert", where the visitor can, using a touch screen interface, select from a list of several questions from the frontiers of biomedical technology and select any one from a panel of experts to answer the question in a pre recorded video format. There is an automated quiz, where random questions related to the topics covered in the Gallery, with special emphasis on the paradigm shifts can be answered by three teams of participants. The Final exhibit talks of the far future, and what we can expect in these different fields that were talked about in the exhibits in the coming decades.

A highly interactive format exhibit "Ask the Expert".

The Gallery is richly supplemented by supporting information in the form of graphics showing the pioneers who brought about change, the changes that they brought about, and the ways in which these changes affected the overall health scenario of the society, the aim again being to emphasise that biomedical technology advanced not linearly, but as a series of singularities that constituted a Biomedical Revolution.

Learning Experiences from the Gallery

Three categories of view changes that visitors experience, when they visit places like Science Centres have been identified. These are changes in -

- *Opinions* : People's immediate thoughts and feelings about a topic those are relatively easy to manipulate
- *Attitudes* : More strongly held beliefs about the world and how it works
- *Values* : underlying and strongly held beliefs (e.g. belief in God, animal rights, the death penalty) which are formed early in life, are very difficult to change and tend to harden as the person grows older[39].

Given that most researchers believe that visitors are likely to have chosen to visit the Science Centre / Gallery on the basis of their matching attitudes and values, one would assume that a gallery can perhaps best try to change opinions, that too minimally, on the topic it attempts to portray[40].

Though this gallery was a part of a Centre that was built by the National Council of Science Museums to be handed over to another agency for operation, and not much time was available for a detailed study, the author did spend a few days taking around select groups of students of the age group 14 -18 through the Gallery. Though the sample was small, the understanding that emerged from interaction with these visitors is that there was a significant shift in opinion. Most students, were not aware that advances in Biomedical sciences occurred not just as a continuum of accumulation of related knowledge, but significantly as a result of a series of paradigm shifts in understanding. But post visit, the opinions expressed by the visitors, as evinced in comments like "In that case I can do something that will cure AIDS too" (a 14 year old girl) or "That means even non biology students can contribute to the growth of biomedical sciences" (a 17 year old boy) show that the idea of paradigm shifts contributing to revolutionary changes was well received. Some students even attempted to hypothesize wildly by tossing about ideas like infusing chloroplast into the skin cells of human beings so as to allow them to synthesize glucose from sunlight and not depend on plants for food. In fact I would go to the extent of saying that even attitudes and values were seen to be changing in a small way when opinions like a positive attitude towards Euthanasia, organ transplants, stem cell research etc. were expressed, and especially when one visitor who said that medicine is perhaps a noble profession (which he had some doubts about, owing to certain personal negative experiences). I add the caveat that the samples studied were small and the average age of the students studied was impressionable. Nevertheless, it is felt that the Gallery indeed did serve the purpose of creating opinion and to a very small extent to modify attitudes and values.

Conclusion

A science advances not linearly, as a cumulative addition of new knowledge gathered as a refinement of the existing corpus of knowledge, but in distinctly discrete spurts, aided by thought lines arising from totally unrelated fields, which are often radically different from existing lines of thought. While this is true of all sciences, it is especially true of medicine and that is what is sought to be established in this Gallery on the Biomedical Revolution. A Gallery portraying this concept can change not just the views of the visitor regarding perception of the history of science but also influence attitudes and values to a limited extent.

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